INTRODUCTION

The maxilla and mandible consist of the basal bone, which is the portion of the jaw located apically, and the alveolar process that is the portion of the jaw bones that forms the alveoli or alveolar processes (Hassell, 1993). These anatomic entities play an essential role in determining the overall success of the future periodontal therapies such as implant dentistry and periodontal regenerative regimes (Hassell, 1993). The cause of these differences is the unique dependence between the morphology of the alveolar process and the teeth and the bone contour. This normally conforms to the prominence of the roots with intervening vertical depressions that taper towards the margin. In a healthy periodontium the position of the bone margin mimics the contour of the cemento-enamel junction and lies approximately 1 to 2 mm apical to it, resulting in the inter-proximal bone being more coronal in height than the labial and lingual/palatal bones (Abdelmalek and Bissada, 1973; Becker et al., 1997). This ‘scalloping’ of the bone on the facial and lingual/palatal areas is related to the tooth, the root form and the tooth position in the alveolus. The bony architecture varies from the anterior to the posterior regions, the molar teeth showing less scalloping and a more significantly flat profile as compared to the bicuspids and the incisors (Abdelmalek and Bissada, 1973; Becker et al., 1997).

Tooth extraction is a traumatic procedure that jeopardizes the surrounding alveolar bone and soft tissues. Healing of the extraction socket involves several biochemical and histological events that lead to alterations in the alveolar bone architecture (Al-Askar et al., 2013; Al-Shabeb et al., 2012). It was reported that buccal plate of the alveolar process is composed solely of bundle bone (Araujo and Lindhe, 2005). In a recent histological study on baboons, the extraction socket classification (ESC) was proposed on the histological finding that the buccal bone receives an essential share of its vascular supply from interdentally blood vessels and not the extraction of multiple contiguous teeth, the interdentally blood supply to the alveolar bone is compromised to a much greater extent than when a single tooth is extracted (Al-Hezaimi et al., 2011). Similar results were reported by another study on beagle dogs (Al-Askar et al., 2013). Al-Shabeb et al. (2012) showed that alveolar bone remodeling around fresh extraction sites occurs in a standardized pattern regardless of the jaw location. Several therapeutic regimes have been proposed in an attempt to prevent or minimize buccal bone remodeling following tooth extraction (Casado et al., 2010; Lekovic et al., 1998). It is evident that the buccal bone architecture plays a significant role in maintaining the overall shape of the alveolus (Al-Hazmi et al., 2013; Fiorellini and Nevins, 2003). It is also clear that the treatment strategy following tooth extraction and success of dental implant therapy is largely dependent on the anatomy of the alveolar process with particular emphasis on the buccal bone (Araujo and Lindhe, 2005; Fiorellini and Nevins, 2003) merely from the buccal bone (Al-Hezaimi et al., 2011).

ABSTRACT

The alveolar processes are major anatomic components of the periodontium. Among all bones the alveolar process structure and morphology are considered unique due to their dependence on the teeth, which are housed in the alveoli. This teeth dependence commonly results in two encountered situations: dehiscence and fenestrations, which represent interruptions of the cortical plate contour.

Key words: Alveolar bone thickness, periodontium, mini implant, dental implant.
ALVEOLAR BONE

The alveolar process is the osseous tissue of the maxillary and mandibular jaws which houses and supports the sockets of the teeth. The process consists of an external cortical plate, the inner socket wall known as the alveolar bone proper and is compact bone, and a cancellous trabecular bone in between the two boney layers. The bone is typically thicker in the palatal and lingual areas when compared to the buccal areas.

The alveolar bone proper is cribriform in appearance and this allows for a connection to the neurovascular structures. The structure and morphology of the alveolar process dependent on the tooth the crest of the osseous alveolar alveolar margin normally follows the contour of cement enamel junction of teeth (Hassel, 1993). The bone is created by osteoblasts during development (modeling) and is constantly remodeled throughout life from the intricate osteoblastic/osteclastic relationship. Bone remodeling consists of an ordered and predictable sequence of bone resorption followed by bone formation. The osteoblasts produce collagen, glycoproteins and proteoglycans to produce the bone matrix that is then mineralized with calcium and phosphate. The mineral is hydroxyapatite and the mineral content is about 60%. When osteoblasts have layed down osseous tissue they become trapped within the tissue and are termed osteocytes (Cochran, 2008).

Osteocytes reside in lacunae and connect and communicate with each other through canaliculi. A group of osteocytes surround themselves around the neurovascular bundles (Haversian canals) and are termed osteons. An osteon is the fundamental unit of compact bone and are cylindrical structures. Volkmann's canals which run within osteons carry nerves and blood vessels, and are perpendicular to the Haversian canals. An analogy can be that the Haversian canals are elevators of a tall building and the Volkmann's canals are hallways on specific floors (Rose, 2004). Cancellous bone consists of trabeculae and has irregular marrow spaces. Cancellous or trabecular bone is found interdentally. The bone quality of the maxilla and mandible are generally different and overall the maxilla has more cancellous bone compared to the mandible (Newman et al., 2011).

The RANK pathway (receptor activator of nuclear factor-κ) which is a balance of the ligand for RANK (RANKL) and a competitive inhibitor osteoprotegerin (OPG) regulates the interaction between the osteoclasts and osteoblasts. The creation of RANKL involves osteoblasts themselves which activate precursor cells to differentiate in the presence of macrophage colony stimulating factor to become osteoclasts (Cochran, 2008). Layers of connective tissue called the periosteum cover the outer surface of the bone. The periosteum contains osteoblasts, stem and progenitor cells, fibroblasts, and vascular and nervous tissues. The inner layer of the bone is lined with endosteum which is comprised of connective tissues containing osteoblasts (Garant, 2003).

RESORPTION OF BONE AFTER EXTRACTION OF TEETH

The alveolar process is a tooth dependent tissue that develops in conjunction with the eruption of the teeth. Further, the volume as well as, the shape of the alveolar process is determined by the form of the teeth, their axis of eruption and eventual inclination (Schroeder, 1986). Subsequent to the removal of all teeth in the adult individual, the alveolar processes will undergo atrophy and reduction of the hard tissue of alveolar bone (Allegrini, 2008; Nevins, 2012). Clinical and radiographic study by Schropp et al. (2003) demonstrated that marked alterations of the height and width of the alveolar ridge will occur following single or multiple tooth extractions. The healing process following tooth removal apparently resulted in more pronounced resorption on the buccal than on the lingual/palatal aspects of the ridge. Their results proved that “approximately two thirds of this reduction of the width of the alveolar ridge that occurred within the first 3 months after tooth extraction.

Camargo et al. (2000) evaluated the clinical effectiveness of bioactive glass used as a graft material combined with calcium sulfate used in the form of a mechanical barrier in preserving alveolar ridges after tooth extraction. He suggests that treatment of extraction sockets with a combination of bioactive glass and calcium sulfate is of some benefit in preserving alveolar ridge dimensions after tooth extraction.

Pietrokovski and Massler (1967) studied the amount of tissues lost after unilateral tooth extraction and used plaster casts models for the dimensional assessments. They concluded that the buccal bone plates both in the maxilla and the mandible were resorbed considerably more than the corresponding palatal/lingual bone walls and that the center of the ridge, as a consequence, shifted palatally/lingually. Further, the process that resulted in tissue reduction seemed to be more pronounced during the initial phase of wound healing than during later periods following tooth removal.

Animal study by Cardaropoli et al. (2005) clearly established that following tooth extraction, the buccal and lingual walls of the alveolus undergo substantial resorption. The bundle bone was resorbed completely as a result of a lack of supporting function of the tooth following its extraction. Because the thin buccal wall is predominantly composed of bundle bone, its resorption had to result in a vertical reduction of the buccal bony crest. However, for the wider lingual crest that is also comprised of substantial proportions of lamellar bone, less vertical reduction was observed. Moreover, resorption occurred on the outer surfaces of both bony walls (Araujo and Lindhe, 2005) Cardaropoli et al. (2003) studied bone modeling and remodeling that occurred within the extraction socket following the
removal of the distal root of mandibular premolars. From the examination of mesio-distal sections it was observed that:

(i) Woven bone filled the extraction socket after one month;
(ii) A cortical ridge including woven and lamellar bone had formed after 3 months;
(iii) After the 3 months interval woven bone was gradually replaced with lamellar bone and marrow.

Denissen et al. (1993) studied the preventing alveolar ridge bone mass loss by implant therapy. He suggested that immediate placement of implants into extraction sockets may preserve the bony architecture. It was reported that immediate implant placement in fresh extraction sites may prevent alveolar bone remodeling in the short term; however, localized osseous defects around immediate implants placed in fresh extraction sites may present a challenge to the clinician (Belser et al., 2007).

Araujo et al. (2005) demonstrated that immediate implant placement into extraction sockets was not able to prevent this remodeling process, and hence could not prevent resorption of the buccal bony wall following tooth extraction. The remodeling process of the buccal and lingual bony walls of extraction sockets is still uncertain. However, the analysis of a recent study revealed that the width of the buccal bony wall may have a significant influence in determining its resorption pattern (Ferrus et al., 2010).

In a clinical study of implant placement into healed sites, facial bone thickness was determined at the time of implant installation and after a healing period of 3 to 6 months using calipers. Significantly greater facial bone loss was observed as the facial bone thickness decreased. Sites with more than 3 mm of bone loss showed the lowest mean facial bone thickness (1.3 mm). Conversely, sites exhibiting no change in facial bone response had a mean thickness of 1.8 ± 1.10 mm at implant installation. It was concluded that the critical thickness of the facial bone plate to reduce facial bone loss was around 2 mm (Spray et al., 2000).

Qahash et al. (2008) evaluated the healing dynamics at buccal peri-implant sites in relation to the dimensions of the alveolar ridges in a dog model. Fluorescent bone labeling revealed that the extent of buccal bone resorption was associated with the width of the alveolar ridge. This association was non-linear and a 2 mm threshold accounted for this non-linearity. This association was twice greater when the buccal alveolar ridge was less than 2 mm as compared with greater width. It was concluded that the buccal alveolar ridge width should be at least 2 mm wide if the alveolar bone level on the facial aspect was to be maintained. In a recent publication by a panel of experts and master clinicians in the field of implantology, clinical guidelines were elaborated for implant placement in the esthetic anterior healed sites. Once the implant osteotomy site was performed, an ideal buccal bone width of 2 mm was recommended to achieve an optimal biological and esthetic outcome. This thus, seem to agree that ideally a minimum of 2 mm of buccal bone wall is mandatory once the implant bed has been prepared in a healed site to ensure proper soft tissue support and avoid the resorption of the facial bone wall following restoration. If this minimal requirement is not met, then the augmentation ridge procedure (before or at implant placement) should be performed to obtain this minimal dimension (Belser et al., 2007).

Vera et al. (2012) suggested that a minimal buccal alveolar bone thickness of 1 to 2 mm is required to maintain the tissue architecture following tooth extraction and implant placement. They evaluate the thickness of buccal alveolar bone at the maxillary first premolars and anterior teeth and found that the buccal alveolar bone thickness at anterior tooth positions is typically less than 1.0 mm thick, and in premolar teeth possess greater buccal alveolar bone thickness than anterior teeth, and the median vertical distance from the cementoenamel junction to the buccal bone crest of 2.79 mm was consistent among all sites measured. Clinicians should keep in mind, prior to extraction, that maxillary anterior teeth typically possess a thin buccal plate.

Loss of alveolar bone may be attributed to a variety of factors, such as endodontic pathology, periodontitis, facial trauma and aggressive moves during extractions. Most extractions are done with no regard for maintaining the alveolar ridge, but a traumatic extraction maintains the alveolar ridge and minimizes residual ridge resorption (Irinakis, 2006). Tooth extraction results in alveolar bone loss as a result of resorption of the edentulous ridge. An average of 40 to 60% of original height and width is expected to be lost after tooth extraction. This can negatively influence bone volume that is needed for future dental implant placement (Wang et al., 2004).

Nevins et al. (2009) reported that at least 20% of the buccal process of alveolar bone undergoes resorption within the first 12-weeks of tooth loss. Excessive tissue changes can result in unacceptable esthetic deficits ranging from soft tissue asymmetry to facial tissue discoloration, marked tissue dehiscence, or abutment or implant exposure (Chen et al., 2009). Alveolar resorption is a consequence of tooth extraction or avulsion, and dental implant therapy must include thorough consideration of this phenomenon, the fate of the buccal alveolar plate after implant placement in extraction sockets in humans (Manor et al., 2009).

THICKNESS OF ALVEOLAR BONE

Alveolar bone thickness in relation to placement of mini screw

Champy et al. (1978) demonstrated that using miniplates
and screws along the ideal line of osteosynthesis provides sufficient support and stability to the bone fragments to allow immediate function. Deguchi et al. (2006) evaluated cortical bone thickness in various locations in the maxilla and the mandible to determine the acceptable length and diameter of the mini-screw for anchorage during orthodontic treatment. Data showed that the safest location for placing mini-screws might be mesial or distal to the first molar, and an acceptable size of the mini-screw is less than approximately 1.5 mm in diameter and approximately 6 to 8 mm in length. Liou et al. (2007) measured the thickness of the infrazygomatic (IZ) crest above the maxillary first molar at different angles and positions to the maxillary occlusal plane. These measurements were then used to derive clinical implications and guidance for inserting mini-screws in the IZ crest without injuring the mesiobuccal root of the maxillary first molar. They concluded that by adopting 6 mm as the minimal IZ crest thickness for sustaining a mini-screw well throughout treatment and avoiding injury to the mesiobuccal root of the maxillary first molar, the clinical implication for mini-screw placement in the IZ crest of an adult is to insert it 14 to 16 mm above the maxillary occlusal plane and the maxillary first molar at an angle of 55° to 70° to the maxillary.

Beaty et al. (2009) measured thickness in clinical landmark areas of the dentate mandibles of young men and women and found out that clinical landmark areas in young dentate mandibles have thicknesses. The thickness measurements obtained at the sites in this study provided practical reference information for mandibular reconstruction and bicortical screw length estimation. The thickness of buccal bone at the parasympsis and mandibular body, thereby determining the maximum length of non-ocortical screws can be safely placed in these regions without injuring the tooth roots or mandibular nerve.

Results showed that the thickness of the bone is very important in placement of mini screw for the reason that the use of 3 mm screws carries the least risk of injury to the tooth root and nerves during the fixation of fractures between the canine and first molar, while 4 mm screws can be safely used in the region of the second molar. It is important to know the distance from the outer cortex to the tooth apices and to the inferior alveolar canal to avoid injuring these structures. Although the screw should be long enough to provide stability, it should be short enough to also avoid damage to any vital structure (Al-jandan et al., 2013).

The thickness of alveolar bone and placement of mini-implant

Mini-implants have gained considerable popularity due to their low cost, effectiveness, clinical management, and stability (Park et al., 2006). Among the factors related to mini-implant stability, bone density and cortical bone thickness appear to be critical for successful placement. Thin cortical bone has been reported to be a possible cause for loosening of orthodontic mini-implants (Miyawaki et al., 2003).

Moreover, bone thickness is thought to be a major factor for stability because primary retention is achieved by mechanical inter-digitation rather than bone to mini-implant contact at an early stage of healing (Deguchi et al., 2006).

Cortical bone thickness has been reported to increase as the insertion angle of the mini-implant increased. Lim et al. (2008) compared maxillary and mandibular cortical bone thickness and root proximity for optimal mini-implant placement. From the analysis, it was observed that cortical bone thickness depends on the inter-radicular site rather than sex or individual differences. Root proximity mesial and distal to the maxillary and mandibular second premolar indicated the greatest value. Hence, the cortical bone thickness depends on the interradicular site rather than sex or individual differences; buccal cortical bone thickness and root proximity appear to be critical for successful anchoring of a mini-implant.

Measurement of the cortical bone thickness and root proximity in inter-radicular sites depending on levels from the alveolar crest and insertion angles can provide valuable information that may be useful during clinical implant placement as well as, provision of an anatomical map for use during implant placement planning. With regard to root proximity, placement of a mini-implant 2 mm from the alveolar crest may not be clinically applicable because the space between roots and a mini-implant may be insufficient. Placing a mini-implant in the maxilla at the 6 mm level apical to the alveolar crest and with an increased insertion angle would provide better cortical bone to mini-implant contact without root damage. The majority of sites placement at 30_ and 45_ angles and at 4 to 6 mm from the alveolar crest appeared to increase bone to mini-implant contact significantly; however, an exception was observed at the 2 mm level apical to the alveolar crest. The same contact characteristics were reported for the cortical bone thickness in mandible (Lim et al., 2008).

Cassetta et al. (2013) evaluated alveolar cortical bone thickness and density differences between inter-radicular sites at different levels from the alveolar crest and assessed the differences between adolescents and adults, males and females, upper and lower arch, anterior and posterior region of jaws and buccal and oral side. Results revealed that adults show a thicker alveolar cortical bone than adolescents. Alveolar cortical bone thickness and density were greater in males than in females, in mandible than in maxilla and in the posterior region than the anterior. There is an increase of thickness and density from crest to base of alveolar bone.

DEHISCENCE

Fenestrations are isolated areas in which the root is
denuded of bone, and the root surface is covered only by periosteum and overlying gingiva (Koke et al., 2003). Alveolar dehiscence is a defect that results in lowering of the crestal bone margin to expose the root surface. The term "dehiscence" refers to a condition in which "the buccal, and less often the lingual aspect of the root of a tooth is without all or a portion of its bony covering (Watson, 1980). The dehiscence is yet to be fully clarified with regards to both etiology and clinical relevance; dehiscence is regarded as "a consequence of tooth malalignment and not of periodontal-inflammatory bone destruction". Two mechanisms are accordingly conceivable in the origin of dehiscence's which are:

(1) They occur immediately after the tooth eruption as a result of the prominence of the tooth position in relation to the dental arch;
(2) They undergo a secondary development as a result of the thin alveolar housing of the facial surface of the root receding due to influences that is yet to be analyzed (Schroeder, 1986).

The occurrence of dehiscence and fenestration during orthodontic treatment depends on several factors, such as the direction of movement, the frequency and magnitude of orthodontic forces, and the volume and anatomic integrity of periodontal tissues. To avoid these problems, the alveolar morphology must be determined before orthodontic treatment through imaging, which shows bone topography and anatomy (Yagci et al., 2012). Yagci et al. (2012) carried out a test on the presence of dehiscence and fenestration and found out that there was no difference among patients with skeletal Class I, II, and III malocclusions. They found that significant differences in the presence of fenestration were found among subjects with skeletal Class I, Class II, and Class III malocclusions. Fenestrations had greater prevalence in the maxilla, but more dehiscences were found in the mandible.

The prognostic assessment of a periodontium with regards to the possible formation or increase in a recession is hypothesized to be closely linked with the positive diagnosis of an alveolar bone dehiscence. This is not feasible, however, with the technical aids currently at our disposal. It is for this reason that records documented the existence and depths of alveolar bone dehiscence's detected during surgery in vivo under direct inspection in conjunction with studies of jaws and with biometric investigations provide valuable data for prognostic and therapeutic considerations relating to gingival recessions (Gargiulo et al., 1961). Excessive occlusal forces provoke dehiscence, and the alveolar bone dehiscences have been claimed along with other factors to be an important component in the origin of gingival recessions (Hall, 1977).

Löst et al. (1984) studied the depth of alveolar bone dehiscences in relation to gingival recessions. Dehiscence depths were measured in vivo during surgical treatment of 113 teeth with gingival recession in 27 subjects. He found that there are relationships between dehiscence's and gingival recession occurrence in deep site. Gingival recession is an apical shift of the gingival margin with respect to the cementoenamel junction, and bone dehiscence is the essential anatomic pre-requisite for its development (Wennstrom et al., 1996). These predisposing factors contribute to the establishment and/or progression of gingival inflammation and the formation of dehiscence. Clinically, gingival recession is always accompanied by alveolar bone dehiscences. Whether underlying bone dehiscence is developed before or parallel with gingival recession has not been clarified (Yagci et al., 2012).

The orthodontic movement of teeth beyond the limits of the labial or lingual alveolar plate can lead to dehiscence formation, thus, predisposing the patient to recession when there is inadequate plaque control or traumatic mechanical factors. For this reason, clinicians generally correlate gingival recession with inadequate treatment planning or insufficient biomechanical tooth control during the orthodontic therapy (Slutzkey et al., 2008). Nimigean et al. (2009) reviewed the prevalence and distribution of fenestrations and dehiscence's of the jawbones among the Caucasian population to find if any correlations can be established between their occurrence and certain teeth characteristics and to discuss the clinical implications of the defects the alveolar process could have. It is important to help the clinician design and manage treatment in order to clinically correct the conditions and identify the principles of bone augmentation, so that endo-osseous implants can be properly placed.

Guo et al. (2011) evaluated three-dimensional (3D) dehiscence of upper anterior alveolar bone during incisor retraction and intrusion in adult patients with maximum anchorage. They observed that for adult patients with bimaxillary protrusion, mechanobiological response of anterior alveolus should be taken into account during incisor retraction and intrusion. Alveolar bone dehiscence produced by jiggling forces was studied by Nyman et al. (1982) with the aim was to achieve support for the hypothesis that bone resorption, induced by jiggling forces, leaves a component within the supracrestal soft tissue with a capacity of reforming bone. The maxillary lateral incisors and first premolars and the mandibular second premolars in two monkeys were used in the study. Result revealed that buccal alveolar bone reduced in height by jiggling forces and regenerated after discontinuation of the forces. When the jiggling that produces the soft tissue within the buccal bone dehiscence forces was surgically removed, the coronal regeneration of the alveolar bone was markedly reduced. These observations suggest that bone resorption, induced by jiggling forces leaves a soft tissue component with a capacity of forming bone.

Wang et al. (2011) evaluate histologically the healing in acute dehiscence type defects following treatment with Open Flap Debridement (OFD) with or without Porous
Biphasic Calcium Phosphate (PBCP) and found out that PBCP might enhance periodontal regeneration in acute-type labial dehiscence defects. To achieve a more predictable regeneration, the addition of certain stimuli such as growth factors or stem cells incorporated into the PBCP may be of advantage in the study done in beagle dogs.

Park and Wang (2006) used a cellular dermal matrix (ADM) as a barrier membrane in reconstructing non-space making buccal dehiscence associated with simultaneous implant placement in locally deficient ridges. They found after six months of treatment that ADM assisted guided bone regeneration achieved a mean of 86.5% height gain and critical bone thickness of 1.8 mm or greater, with clinical bone density equivalent to that of the native bone.

Al-Hazmi et al. (2013) measurements efficacy of using platelet derived growth factor and xenograft (with or without collagen membrane) for bone regeneration around immediate implants with induced dehiscence type defects and used a micro-computed topographic study in dogs. They found that within the limits of the present micro-CT experiment, it is concluded that Guided Bone Regeneration (GBR) around immediate implants with dehiscence defects using recombinant human platelet derived growth factor (rhPDGF) and xenograft alone resulted in higher buccal bone thickness (BBT), buccal bone volume (BBV), vertical bone height (VBH) and bone-to-implant contact (BIC) than when performed in combination with a collagen membrane (CM).

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